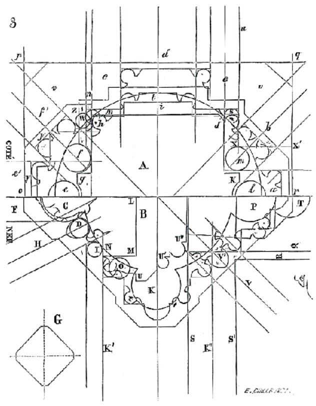
Art du Trait. Considerations on Double Orthogonal Projection in Medieval Stereotomy

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Abstract

The ancient art of stereotomy lies at the origins of the long process of formalizing the method of double orthogonal projection, which found its conclusion at the end of the nineteenth century with Gaspard Monge (1746-1818). Beginning from some statements contained in the famous *Dictionnaire raisonné* of Eugène Emmanuel Viollet-le-Duc (1814- 1879), and in particular under the entry '*Trait (art du)*' the current essay discusses the hypothesis of the use of rigorous projection techniques in the Gothic building site and the ante litteram knowledge of descriptive geometry on the part of medieval artisans. On this theme, the essay offers some considerations regarding the restoration architect's hypotheses, by considering them in view of more recent studies by Italian and French authors in the field of the history of architectural drawing and the history of the codification of forms of representation.

Keywords
Stonecutting, Viollet-le-Duc, Descriptive Geometry, Gothic Building Sites, History of Drawing



Viollet-le-Duc, Comparison between two systems of pillars of naves carrying vaults in arches of ogive. The Paris Cathedral (A); the Reims Cathedral (B). Viollet-le-Duc 1875, p. 207.

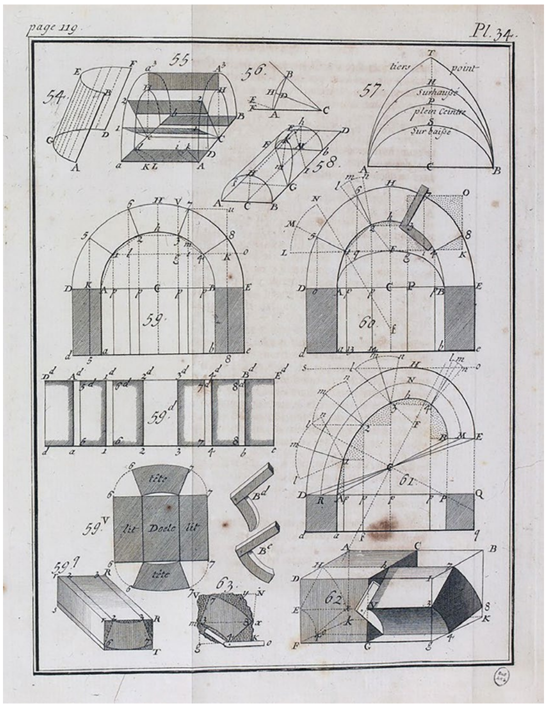
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Introduction

In his monumental *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle* Eugène Emmanuel Viollet-le-Duc (1814-1879) informs us that the builders of Gothic cathedrals possessed advanced skills in descriptive geometry. In particular, under the heading '*Trait (art du)*' (literally art of the line) he explains how the complexity of the vaulted system of the Gothic cathedral necessitated a conception of the plan based on the projection of the roofing elements onto the supporting structures [Viollet-le-Duc 1875, p. 204] (cover image). In effect, the Gothic building site witnessed the introduction of complex stonecutting techniques, which required the ability to conceptually operate in space and exercise skill in the drawing of elements at full scale. However, caution is due as regards the French architect's assertion of widespread use of double-orthogonal projection drawings at this historical stage, and even more so of expertise in descriptive geometry among the building-site workers. By studying these assertions in context with the subsequent studies on the history of architectural drawing, and the history of the codification of forms of representation, we can gain greater clarity and understanding of why Viollet-le-Duc proposes a substantial identification between stonecutting skills and descriptive geometry, and how this can be explained, in good part, through the events that mark the origination of the method that was developed by Gaspard Monge (1746-1818).

Gothic building site and double orthogonal projection

A well-known drawing depicting the Cathedral of Milan, dated about 1389 and attributed to Antonio di Vincenzo [1], is to date the earliest known example in which two distinct views, a plan and a (partial) vertical section, are explicitly placed in relation [Sakarovitch 1998, p. 45]. Viollet-le-Duc, however, confidently attributes the systematic use of double orthogonal projections in architecture to builders as early as the twelfth century. The fact that the Gothic building site expanded from the Romanesque one and consequently required increasing coordination between the various figures is indeed interpreted by the architect as proof of the existence, as early as medieval times, of an architectural drawing characterized by conscious and thorough use of geometry – and even descriptive geometry – and properly endowed with 'precision'. More specifically, under the entry '*Art du trait*' of his *Reasoned Dictionary* the architect analyses the construction procedures for the Saint-Denis ambulatory, and states that the realisation necessarily demanded the tracing of projections of the vault arches, in the same drawing, in horizontal plane and in vertical plane [Viollet-le-Duc 1875, entry *Trait (art du)*, pp. 197-214; Sakarovitch 1998, p. 124]. The term '*trait*'denotes, in this context, a decomposition of the different planes that make up the solids to be put in place in the construction, and is defined by Viollet-le-Duc as a descriptive geometry operation involving the drawing of the horizontal and vertical projections, sections, and reverses of the different parts of a construction. Moreover, according to the author, advanced techniques of *art du trait* had been known in Greece since Antiquity, in Egyptian civilization, and in the Orient, and it was precisely in Syria that the first crusaders would have come into contact with such knowledge of construction, leading later led to the developments of Western architecture in the twelfth century [Viollet-le-Duc 1875, entry *Trait (art du)*, pp. 197-8].
Twentieth-century studies on the history of stonecutting methods agree that it was the construction of Byzantine domes and certain elements of Arab monuments that opened the way to the complexity in drawing and stereotomy operations that would characterise the medieval cathedrals [Taton 1986, p. 77]. However, analysis of the historical development of stonecutting techniques indicates how very unlikely it is that such a thorough geometric knowledge could have been found, in those lands, by the European crusaders [Sakarovitch 1998, pp. 111-126] (fig. 1).
It is then important to distinguish between the drawing of an entire building or parts of it (plan and relative vertical sections), and the drawing for *coupe de pierre* (stonecutting), which was a specific and autonomous practice. From the first development of the Gothic



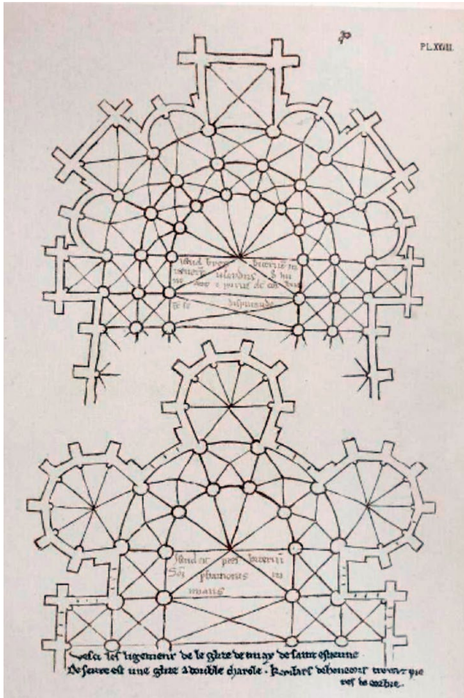


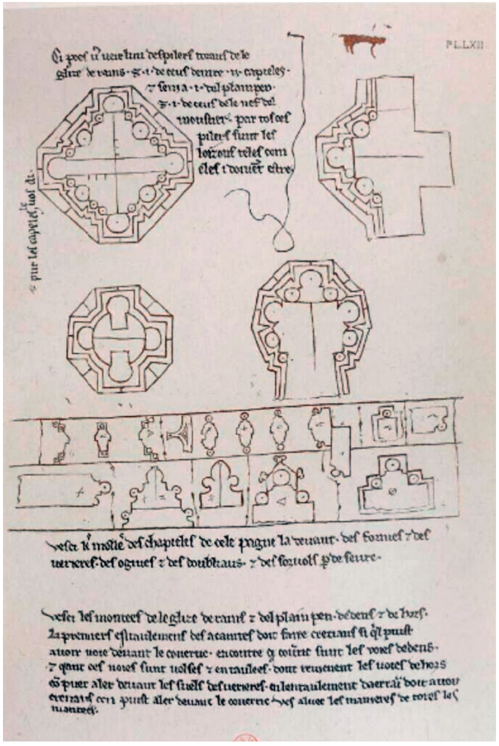
Fig. 1. Methods of stonecutting. Frézier 1737-1739, Vol. 2, *planche* 34, p. 119.

Fig. 2. Drawings from the Album of Villard de Honnecourt. Plans of two churches. Lassus 1858, *planche* XXVIII, folio 15° recto.

construction system, the drawing for the *coupe* required a certain mastery of the concepts of projection and reversal and their relative application, and in fact the complex nature of the vaults, and the consequent difficulty of determining the ashlars intended to compose them, testifies to such mastery. This kind of operation, however, was not carried out on the basis of indications specified in advance, but rather by following a traditional, empirical method based on a set of rules, largely developed in relation to the tools themselves, and which show that the drawing for cutting the stone (*trait de coupe)* was essentially an artisanal technique [Savignat 1983, p. 136]. These rules, René Taton recalls, constituted a kind of catechism that skilled craftsmen (*compagnons*) learned by heart, and were passed on from father to son, from master to apprentice [Taton 1986, p. 77]. The drawings found in the *Album* of Villard de Honnecourt [Erlande-Brandenburg et al. 1987; Lassus 1858] (figs. 2-4), to which Viollet-le Duc refers [Viollet-le Duc 1875, p. 211, Bressani 2014 p. 344-5] (fig. 5) have been the subject of analysis by several authors, intent on better identifying the geometric procedures relative to the drawings and their not always clear titling [Sakarovitch 1998, pp. 126-129; Bechman 1987, pp. 43-55]. In any case, both the scarce plans and diagrams that probably allude to stonecutting techniques reveal, even to the untrained eye, an approximation that distinguishes them from the precise and articulate representations dealing with the same constructional problems in the modern period.

The attribution of the birth of descriptive geometry in the Middle Ages is therefore improper. In order to understand Viollet-le-Duc's assertions, however, it may be useful to consider the role played by architectural drawing in the medieval building site, and the turning point it represented during the long process that led from the first empirical and intuitive plans of buildings and cities of antiquity to the abstract and theoretical conception of double orthogonal projection.

The extent of Gaspard Monge's intervention in the process of formalising the geometry that he called 'descriptive' is not universally shared by scholars [Migliari 1996]. We can affirm, however, that such geometry is acquired in codified form in the context of French culture in the second half of the eighteenth century, and that in that context, a rigorous method for representing the three dimensions of objects on the two-dimensional plane finds definition [Ugo 1994, pp. 98-105]. The origins of what was to become the geometry of Monge can nevertheless be traced within the history of construction. In the medieval building site, in fact, structures are more complex, and less room is therefore allowed for improvisation



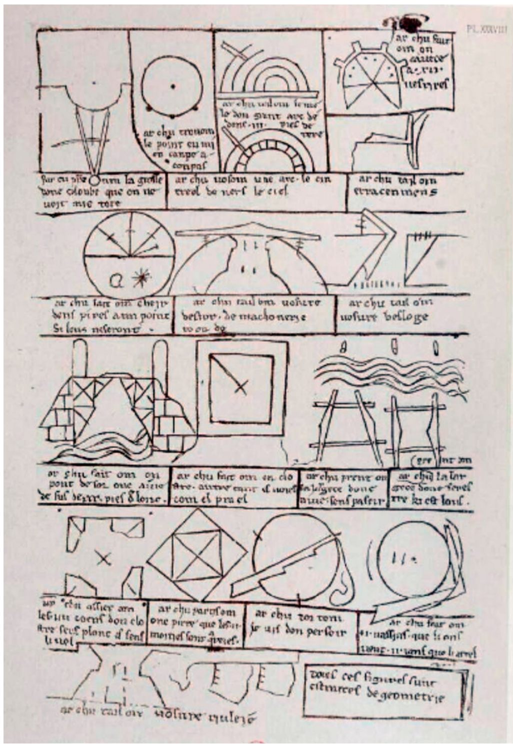


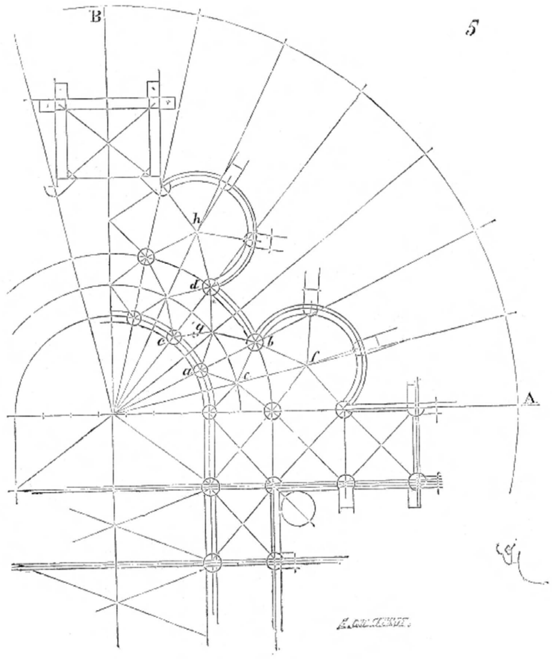
Fig. 3. Drawings from the Album of Villard de Honnecourt. Pillars of the church of Reims. Lassus 1858, *planche* LXII, folio 32° recto. These plans were used to cut patterns to apply to the stone so as to trace the shape that was to be given to it. Lassus 1858, p. 215.

Fig. 4. Drawings from de Album of Villard de Honnecourt. Lassus 1858, planche XXXVIII, folio 20° recto. According to Lassus these simple sketches and the summary explanations given under each one indicate a part of the knowledge in practical geometry that the architect had in the XIII century. Lassus 1858, p. 145.

during construction, which makes ready and confident communication between diverse operators crucial [Sakarovitch 1998, pp. 1-14]. This issue concerns the figure of the *appareilleur* in particular. These were the artisans, in the role of intermediary between *tailleur de pierre* and architect, in charge of preparing the *épures* (technical drawings), which then made it possible to determine the shape of the ashlars, which once assembled, would constitute the staircases, vaults, domes, and so on [Perouse de Montclos 1989, entry *Appareilleur*]. These are therefore design drawings, necessarily endowed with a certain degree of precision, as each block must conform to a strict geometric definition, not to mention that the realisation of the work may require coordination among several stonecutters [Sakarovith 1998, pp. 11-13].

Descriptive and stereometric geometry

In his studies devoted to Monge's role in the process of mathematization of graphical techniques [Taton 1951, 1986], Taton recalls the empirical aspect and often approximate nature of the complex and obscure rules of medieval stereotomy, yet as their foundation, he acknowledges a high capacity for intuition of the figures of space and the properties of projections [Taton 1986, p. 77]. In this sense, it can be affirmed, as does Joël Sakarovitch, that it will be precisely these *appareilleurs* who would explore the potential of the double orthogonal projection method, marking a key step in the formulation of descriptive geometry [Sakarovitch 1998, p. 97]. This powerful new method for understanding, visualising, and representing forms in space was thus born in the address of practical problems, and independent of any theory, whether architectural or geometric.
To better understand the close connection between descriptive geometry and stereotomy [Calvo López 2016], it would be useful to retrace some passages of Monge's teaching activity: particularly in the context of the complex events of the late 18th century involved in reforming the institutions for education of engineers. In that context, the knowledge required for the art of stonecutting was considered a technical tool, suitable for use for propaedeutic purposes, aimed at an abstract definition of the geometric elements of space. The young Monge, a teacher at the *École du Génie de Mézières* since 1764, had demonstrated particular



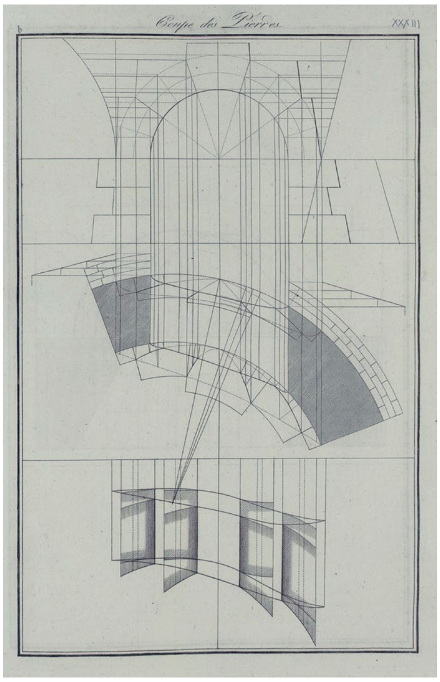


Fig. 5. Viollet-le-Duc, *plan of the choir of Notre-Dame de Vaucelles of the order of Cîteaux*. Apse layout (*tracé*). Viollet-le-Duc 1875, p. 212. The drawing is aimed to explain how Villard d'Honnecourt's vaulted buildings plans derive essentially from the structure of the vaults.

Fig. 6. A page from Analysis applied to stereotomy by Gaspard Monge. Monge, de Prony 1795, *planche* XXXIII

ability in solving problems of military strategy in exceptionally rapid times: an ability which can be explained by his early formulation of the method of double orthogonal projection, which for a long time, however, he would not be allowed to disseminate or pass on to his pupils, for contingent reasons such as military secrecy, rivalry between the different institutes and perhaps even a certain hostility against his person [Cardone 1996, pp. 7, 69-70].
It should be noted that at Mézières Monge taught precisely "*théorie de la coupe des pierres*" (theory of stonecutting). This was a traditional discipline in the training of engineers, to which Chastillon, director since the founding of the '*école de pratique*' (school of practice) section, had accorded an importance that went far beyond the acquisition of a construction technique that was already in decline (fig. 6). To this teaching, in fact, he ascribes the fundamental objective of training in geometry and the view of space, as stipulated in the institution's own regulations [Sakarovitch 1998, p. 219-221]. It would not be until after the revolution that the scientist could teach a course in descriptive geometry, first at the *École Normale* and then at the *École Centrale des Travaux Publics*, later the *École Polytechnique,* where he was called by the revolutionaries to participate in building the new ruling class. In the curriculum, formulated by Monge himself, he could finally put into action his intentions for reform in the transmission of scientific knowledge, which he conceived as a bridge between theory and practice. And it is indeed the formulation of a new clear and effective scientific and geometric language that allows theory and practice to be brought together in a unified vision [Cardone 1996, pp. 14-15, 24].
The documents that have come down to us in this regard are fragmentary, nevertheless Sakarovitch recognizes, in the teaching at Mézières, the fundamental geometrical tools contained in the discipline formalised 20 years later. Noting then that, although this is a geometrical theory applicable to various practical or abstract problems, in fact the discipline no longer falls within the field of stereotomy, Sakarovitch questions the specific reason for the title, "*théorie de la coupe des pierres*" (theory of stonecutting), rather than others possible, for example "*théorie de la coupe de bois*" (literally wood cutting theory) or more generically "*théorie du dessin d'architecture*" (architectural drawing theory) which would deal with such theory in carpentry or overall architectural design. The motivation lies, above all in the fact that the geometric instruments used by the *appareilleurs* are richer than those found in architectural treatises, which make use of practically only double projection, and more comprehensive than those found in treatises on the construction of wooden structures,

which do not use auxiliary planes at all [Sakarovitch 1998, p. 243]. There are, however, also motivations arising from a substantial conceptual affinity between the material operations associated with the *coupe des pierres* and the geometric abstraction of a three-dimensional space proper to descriptive geometry. The stonecutter faced with the stone ashlar is dealing with a three-dimensional volume in the same way as the scholar of geometry, and with his tools he can essentially reach within the ashlar any point he wishes. Stonecutters also, like carpenters, need a life-size drawing (usually traced on the ground or a wall) which is called *épure* [Perouse de Montclos 1989, entry *Épure*] and which presupposes a drawing of essential character, composed with only the strictly necessary lines. In this sense, these medieval artisans become the bearers of a "tradition of an economy of representation" of which Monge – albeit with different objectives – would become the continuator [Sakarovitch 1998, p. 244]. Moreover, the hypothesis that Monge's theory, as a scientific systematisation and acquirement of the empirical knowledge of the ancient *appareilleurs*, derives from the discipline of the *coupe des pierres* is shared by other scholars, such as Jean-Michel Savignat, who states that with Monge, the matter of carpentry and stonecutting becomes one of the multiple applications of descriptive geometry [Savignat 1983, p. 143].

Conclusions

On the basis of the considerations proposed here, we thus outline the hypothesis that what distinguishes the theory of *coupe des pierres*, as Monge treats it in the school of Mézières, from descriptive geometry, would be solely the possibility, for the latter, of popularising its knowledge. Sakarovitch, relying on numerous testimonies affirming the secret character of the drawing techniques taught at the *École du Génie*, in fact suggests the possibility that Monge's famous course in descriptive geometry given at the *École Polytechnique*, was, in reality, a way of dealing publicly with the same topics elaborated in his previous institutional role, under the other titling. With this statement, not only is the brotherhood between the ancient practices of stereotomy and descriptive geometry further reaffirmed, but there even looms a substantial identity between the latter and a series of geometrical principles and tools that derive from the ancient empirical science, and that retain the same names, but are already substantially composed under the one Mongian theory. A kind of identification between descriptive geometry and *coupe des pierres* in which Viollet-le-Duc himself, in the heart of the next century, could more or less be consciously participant, was thus emerging in the French scientific milieu of the 18th century. One can thus explain, then, the casualness with which Viollet-le-Duc ascribes an expertise in descriptive geometry to the Cluniac monks of the twelfth century, or even Middle Eastern peoples of the early Christian era.

Notes

[1] <https://www.disegniduomomilano.it/disegni/detail/280/> (accessed 2 February 2023).

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Translations from the cited French and Italian texts are by the author.

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